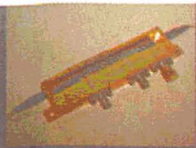
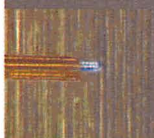
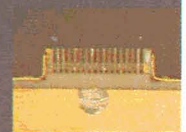


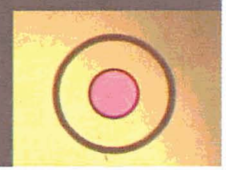
The Optical Fiber Array Bundle Assemblies for the NASA Lunar Reconnaissance Orbiter

Melanie N. Ott, Rob Switzer, William Joe Thomas, Richard Chuska, Frank LaRocca, Shawn Macmurphy


CODE 562 PHOTONICS Group @ GSFC


Melanie N. Ott
NASA Goddard Space Flight Center
Applied Engineering & Technology Directorate,
Electrical Engineering Division,

301-286-0127, melanie.n.ott@nasa.gov
301-286-8813, william.j.thomes@nasa.gov
misspiggy.gsfc.nasa.gov/photonics
NEPP.nasa.gov
Photonics.gsfc.nasa.gov

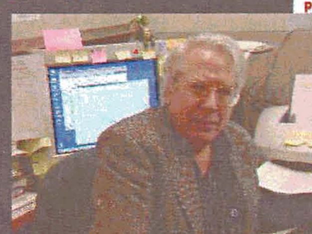
Outline

- Introductions
- LRO (LOLA & LR) Introduction & Requirements
- LRO Solutions
- Design to Integration
  - Lessons Learned
  - Integration
- Conclusions

Mentorship Mapping

Arnold Sommerfeld
Russia, 1868 - 1951
German Physicist
Quantum Theory

Karl F. Herzfeld
Vienna, 1892 – 1978
John's Hopkins University Professor, 1926
Catholic University Professor, 1936



Henning Leidecker, USA,
Catholic University Professor, 1967
NASA Goddard Space Flight Center, 1985
NASA GSFC Chief Parts Engineer, Currently

Students/Nobel Laureates
1) Werner Karl Heisenberg, 1901-1976, Quantum Mechanics
2) Wolfgang Ernst Pauli, 1900 – 1958, Theoretical Physics, uncertainty principal
3) Peter Joseph William Debye, 1884 - 1966 Physics, Physical Chemistry
4) Hans Albrecht Bethe 1906 – 2005, Physics
5) Herbert Kroemer, 1928 -
6) Linus Carl Pauling, 1901 - 1994

Melanie N. Ott

CODE 562 PHOTONICS Group @ GSFC

Melanie N. Ott, Group Leader, 1994-2008
Applied Engineering Technologies Directorate, Electrical Engineering Division

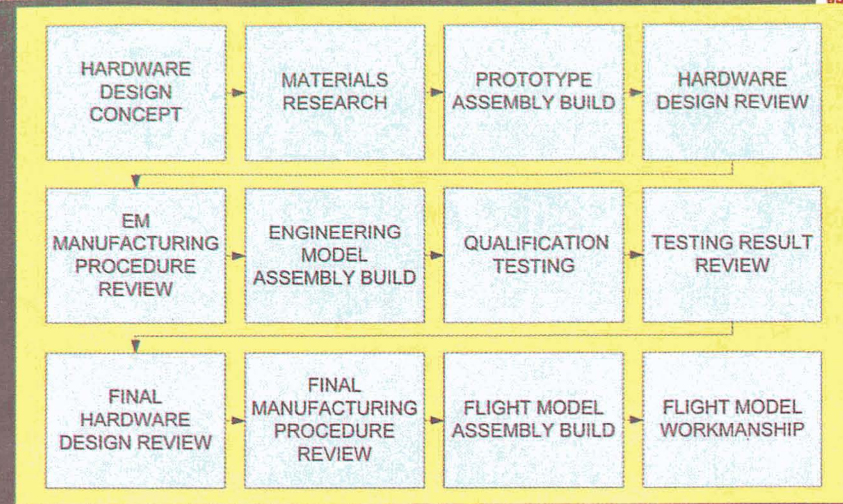
Rob Switzer, Frank LaRocca, W. Joe Thomes, Melanie Ott, Richard Chuska

A Decade of Service from the Photonics Group for Photonics & Optical Fiber Components and Assemblies Code 562, Electrical Engineering Division of AETD, NASA GSFC

Project	Dates	Design	Qualification Performance over Harsh Environment	Manufacturing	Integration	Failure Analysis
ICESAT, GLAS,	1997 - 2005	X	X	GSE		Prototype
ISS	1998 - 2008					Vendor/ Flight
ISS - HDTV	2003	X	X	FLIGHT		
Fiber Optic Data Bus	1997 -2000	X	X			
Messenger – MLA,	2001 - 2004	X	X	FLIGHT	X	
Sandia National Labs (DOE)	1998 -2008		FLIGHT			Vendor/ Flight
ISS-Express Logistics Carrer	2006 -2009	X	X	FLIGHT	X	
Air Force Research Lab	2003, 2008		X			
Shuttle Return To Flight	2004 -2005			FLIGHT		
Lunar Orbiter Laser Altimeter	2003 -2008	X	X	FLIGHT	X	Prototype
Mars Science Lab ChemCam	2005 -2008	X	X	FLIGHT	X	Vendor
Laser Ranging, LRO	2005 - 2008	X	X	FLIGHT	X	Prototype
Fiber Laser HP/IRAD	2003 - 2006	X	X	QUAL		
ESA/NASA SpaceFibre	2008 (TBD)		X	QUAL		

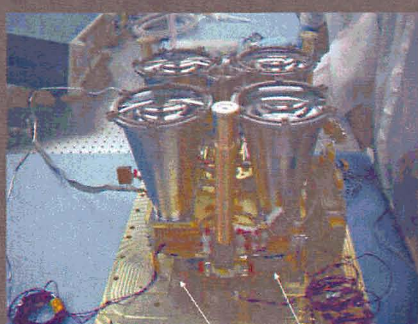
Upcoming is the 3rd Event in coordination with ESA/CNES/JAXA/NASA on optics for space
Publications from work noted above can be found @ **misspiggy.gsfc.nasa.gov/photonics**

How Does the Photonics Group Go from Ideas to Flight?

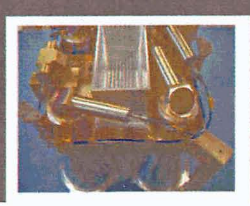


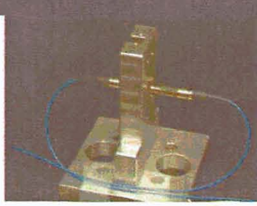
BASIC PRODUCT LIFE CYCLE

Mercury Laser Altimeter 2001-2003



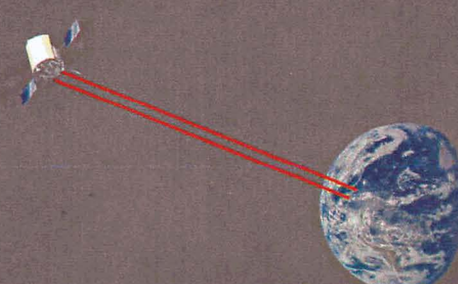
Receiver telescopes focused into optical fiber assemblies that route to different detectors.
The MLA is aboard MESSENGER currently sending data from Mercury!



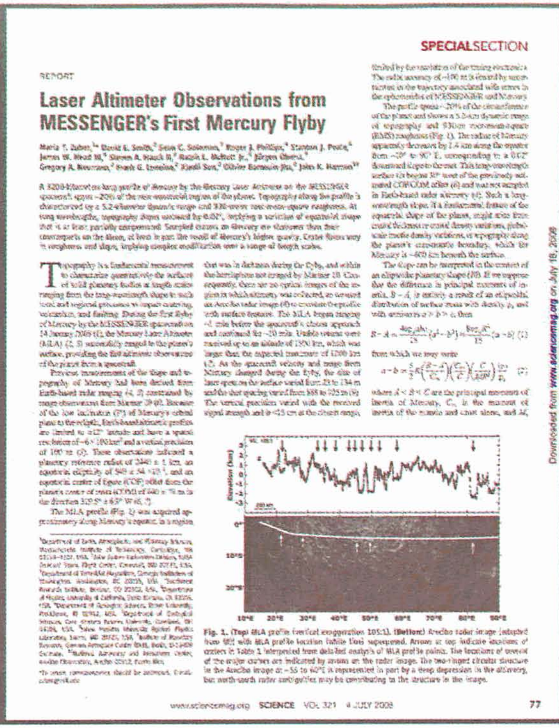


The 24 Million Km Link with the Mercury Laser Altimeter

Jay Steigelman
Dave Skillman
Barry Coyle
John F. Cavanaugh
Jan F. McGarry
Gregory A. Neumann
Xiaoli Sun
Thomas W. Zagwodzki
Dave Smith
Maria Zuber



MOLA Science Team Meeting
Bishop's Lodge, Santa Fe, NM
August 24-25, 2005



SPECIAL SECTION

REPORT

Laser Altimeter Observations from MESSENGER's First Mercury Flyby

GSFC PHOTONICS

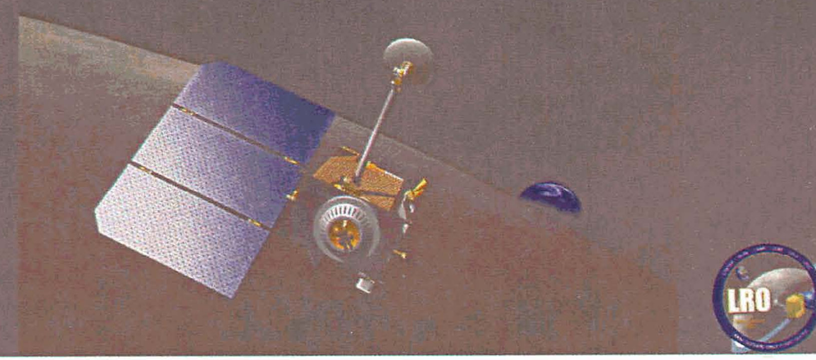
Lunar Reconnaissance Orbiter
NASA Goddard Space Flight Center

GSFC PHOTONICS

The Concept Challenges:

1) LOLA; For the Lunar Orbiter Laser Altimeter (LOLA) Reduce size and weight of previous MLA hardware design from four telescopes into one telescope with fiber based array in a precise compressed pattern.

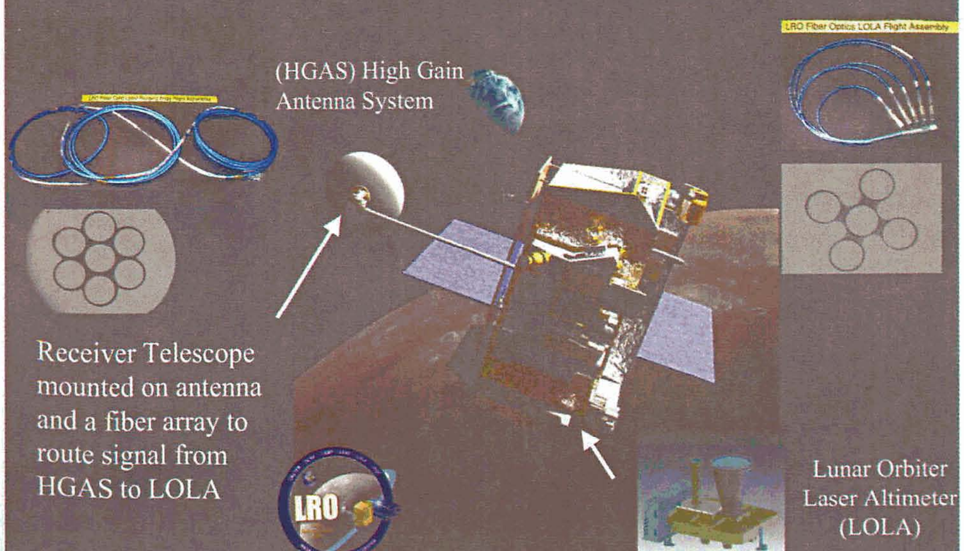
2) LASER RANGING: F or the Laser Ranging Application from Earth,
- carry the signal from the telescope located on the High Gain Antenna system (HGAS)
- Traverse three subsystems, to given detector on LOLA, with high reliability and compactness
- Several interconnections would have to be accommodated for integration subsystem ease.



LRO LRO

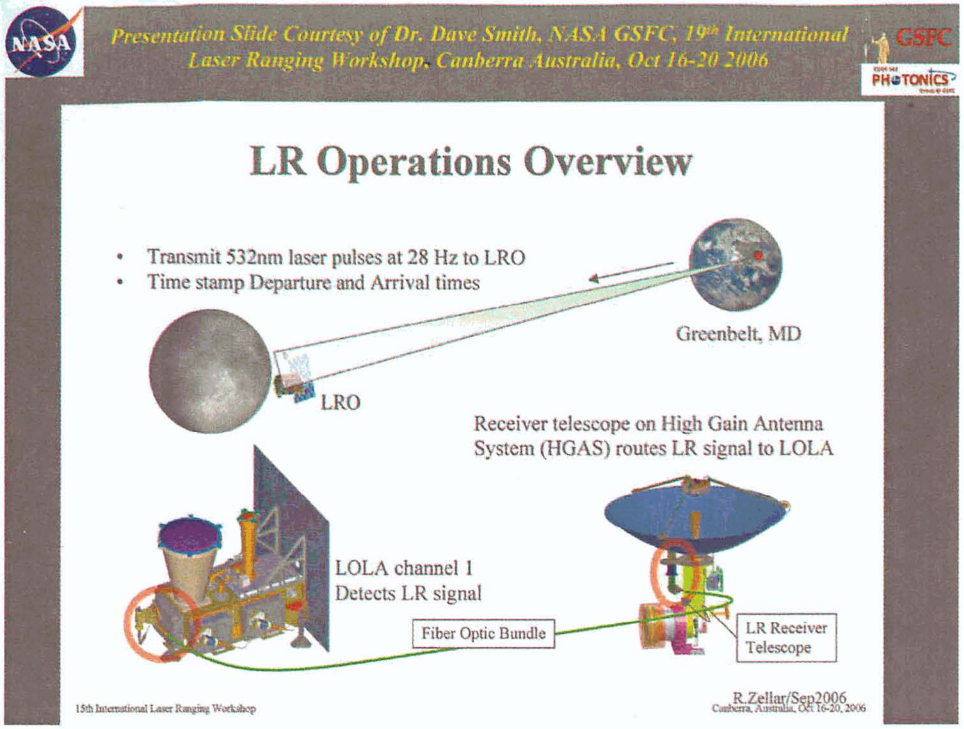
The Lunar Reconnaissance Orbiter; The Laser Ranging Mission and the Lunar Orbiter Laser Altimeter

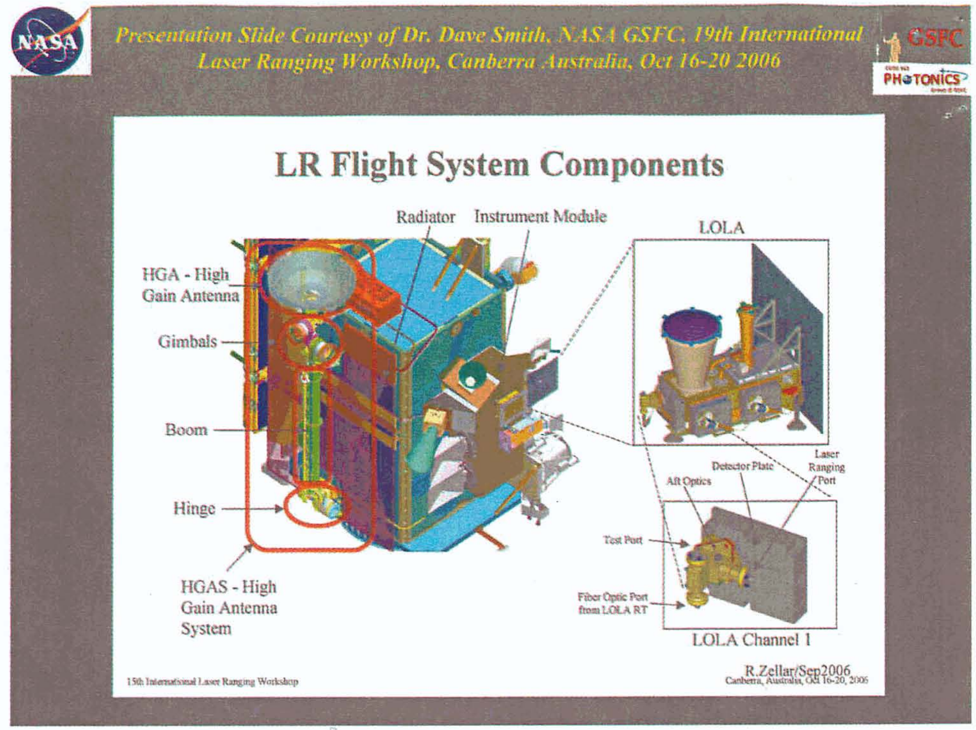
GSFC PHOTONICS

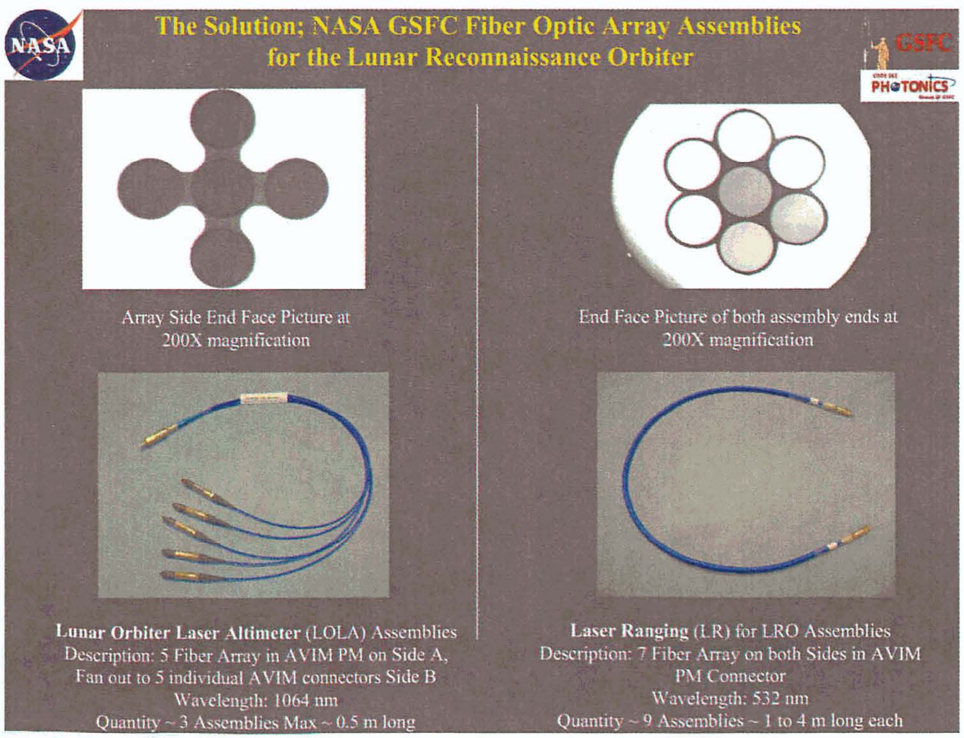


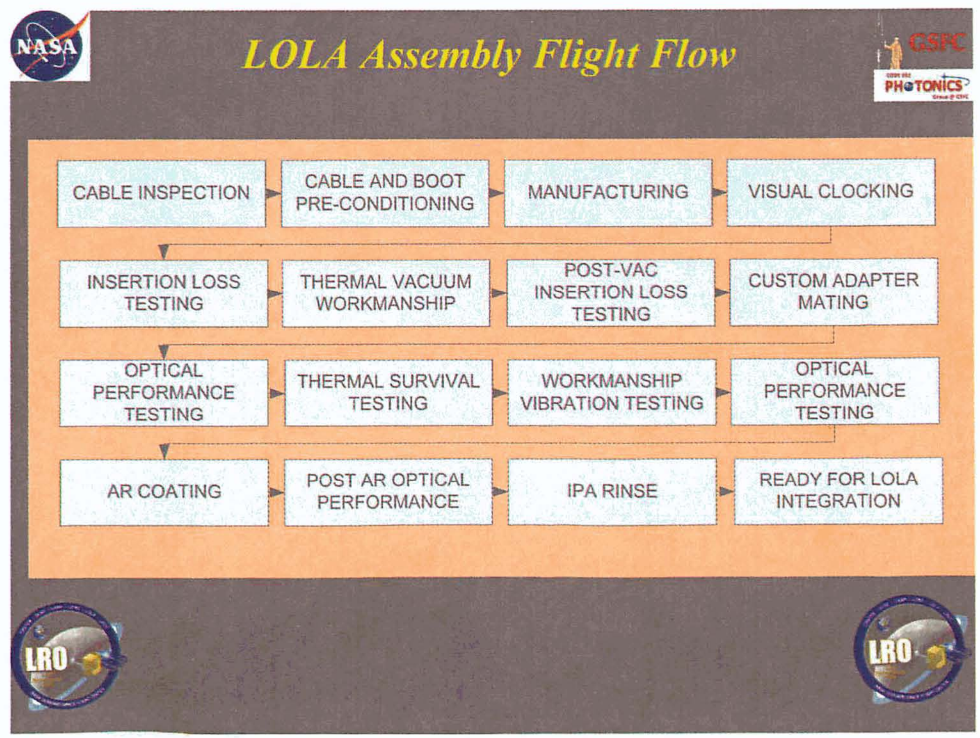
Presentation Slide Courtesy of Dr. Dave Smith, NASA GSFC, 19th International Laser Ranging Workshop, Canberra Australia, Oct 16-20 2006

GSFC PHOTONICS


Presentation Slide Courtesy of Dr. Dave Smith, NASA GSFC, 19th International Laser Ranging Workshop, Canberra Australia, Oct 16-20 2006
GSFC
PHOTONICS
LR Operations Overview
• Transmit 532nm laser pulses at 28 Hz to LRO
• Time stamp Departure and Arrival times
Greenbelt, MD
LRO
Receiver telescope on High Gain Antenna System (HGAS) routes LR signal to LOLA
LOLA channel 1
Detects LR signal
Fiber Optic Bundle
LR Receiver Telescope
15th International Laser Ranging Workshop
R.Zellar/Sep2006
Canberra, Australia, Oct 16-20, 2006


Presentation Slide Courtesy of Dr. Dave Smith, NASA GSFC, 19th International Laser Ranging Workshop, Canberra Australia, Oct 16-20 2006
GSFC
PHOTONICS
LR Flight System Components
Radiator
Instrument Module
LOLA
HGA - High Gain Antenna
Gimbals
Boom
Hinge
HGAS - High Gain Antenna System
Aft Optics
Detector Plate
Laser Ranging Port
Test Port
Fiber Optic Port from LOLA RT
LOLA Channel 1
15th International Laser Ranging Workshop
R.Zellar/Sep2006
Canberra, Australia, Oct 16-20, 2006


The Solution; NASA GSFC Fiber Optic Array Assemblies for the Lunar Reconnaissance Orbiter
GSFC
PHOTONICS
Array Side End Face Picture at 200X magnification
End Face Picture of both assembly ends at 200X magnification
Lunar Orbiter Laser Altimeter (LOLA) Assemblies
Description: 5 Fiber Array in AVIM PM on Side A, Fan out to 5 individual AVIM connectors Side B
Wavelength: 1064 nm
Quantity ~ 3 Assemblies Max ~ 0.5 m long
Laser Ranging (LR) for LRO Assemblies
Description: 7 Fiber Array on both Sides in AVIM PM Connector
Wavelength: 532 nm
Quantity ~ 9 Assemblies ~ 1 to 4 m long each


LOLA Assembly Flight Flow
GSFC
PHOTONICS
CABLE INSPECTION
CABLE AND BOOT PRE-CONDITIONING
MANUFACTURING
VISUAL CLOCKING
INSERTION LOSS TESTING
THERMAL VACUUM WORKMANSHIP
POST-VAC INSERTION LOSS TESTING
CUSTOM ADAPTER MATING
OPTICAL PERFORMANCE TESTING
THERMAL SURVIVAL TESTING
WORKMANSHIP VIBRATION TESTING
OPTICAL PERFORMANCE TESTING
AR COATING
POST AR OPTICAL PERFORMANCE
IPA RINSE
READY FOR LOLA INTEGRATION
LRO
LRO

LOLA Documentation for Configuration Management

Document Name	CM Documentation Number
LOLA Fiber Optic Flight Assemblies	LOLA-OPTICS-WOA-0338
Thermal pre-conditioning on Flexlite 200/220 µm fibers for flight application	562-PHOT-WI-LOLA-TP-001
Preconditioning Procedure for AVIM Hytrel Boots for LOLA fiber optic assemblies	562-PHOT-WI-LOLA-VAC-001
Procedure for Diamond AVIMS PM Kit Pre-Assemble Inspection	LOLA-PROC-0104
Assembly and Termination Procedure for the Lunar Orbiter Laser Altimeter Five Fiber Custom PM Diamond® AVIM Array Connector for the Lunar Reconnaissance Orbiter	LOLA-PROC-0098
Insertion Loss Measurement Procedure For LOLA 5-Fiber Assembly (Open Beam Configuration)	562-PHOT-WI-LOLA-IL-001
Integration of the LOLA Fiber Optic Bundle to the Telescope Adapter	LOLA-PROC-0140
LOLA Fiber Bundle Inspection and Test Procedure	LOLA-PROC-0099

Laser Ranging on Lunar Recon Orbiter 2006-2008

Document Name	CM Documentation Number
Thermal Pre-conditioning on Flexlite 200/220 µm fibers for flight application	LOLA-PROC-0137
Preconditioning Procedure for AVIM Hytrel Boots for LOLA fiber optic assemblies	LOLA-PROC-0138
Diamond AVIM PM Kit Pre-Assembly Inspection	LOLA-PROC-0104
Ferrule Polishing & Ferrule/Adapter Matching Procedure	LOLA-PROC-0139
Assembly and Termination Procedure for the Laser Ranging Seven Fiber Custom PM Diamond AVIM Array Connector for the Lunar Reconnaissance Orbiter	LOLA-PROC-0112
Compression Test Procedure for Fiber Optic Connector	LOLA-PROC-0141
Active Optical Power Optimization Procedure for The Laser Ranging Optical Fiber Array Assemblies	LOLA-PROC-0110
Laser Ranging Fiber-Optic Bundle Optical Test Procedure	LOLA-PROC-0107
Insertion Loss Measurement Procedure for The Laser Ranging Optical Fiber Array Bundle Assemblies	LOLA-PROC-0111
Mating of Two LR 7-Fiber Optical Fibers Using Cleanable Adapter	LOLA-PROC-0142
Cutting Back The Kynar Strain Relief For Integration	LOLA-PROC-0143
Fiber Optic Bundle Inspection and Insertion Loss Measurement	LOLA-PROC-0148

Qualification Testing on Engineering Models

- Array Compression Testing.
- Thermal Vacuum Workmanship Testing, 8 cycles
- Vibration Launch Conditions.
- Thermal Cycling with Active Monitoring (accelerated life)
- Cold Gimbal Motion Testing,
  20,000 Mechanical Cycles with Active Monitoring
- Gimbal Life Testing, 20,000 Motion Cycles.
- Gamma Radiation Testing with Active Monitoring.

Qualification Testing on Flight Models

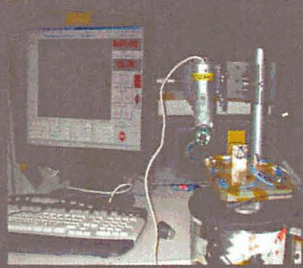
Array Compression Testing.
Thermal Vacuum Workmanship Testing, 8 cycles.
Vibration Launch Conditions, Instrument Levels.

Qualification of Engineering Models

Random Vibration Testing for EMs

Launch vehicle vibration levels for small components (GEVS) (based on box level established for EO-1) on the "high" side.

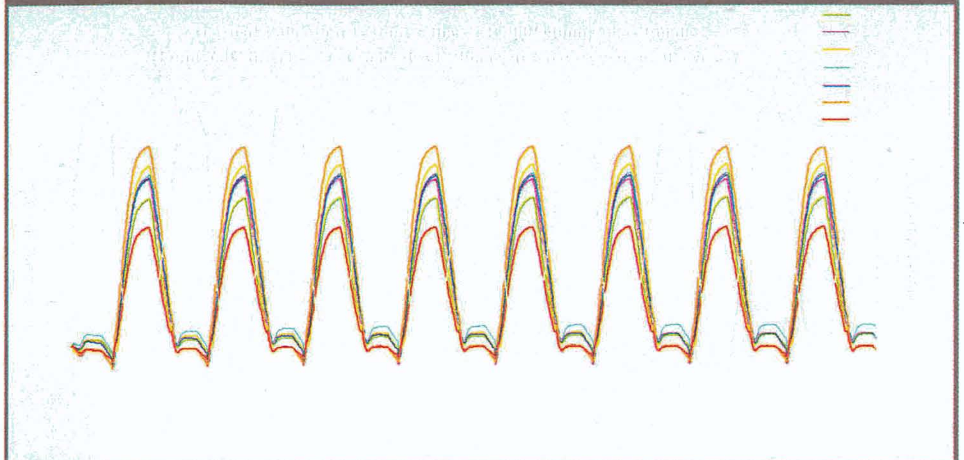
Frequency (Hz)	Protoflight Level
20	0.052 g^2/Hz
20-50	+6 dB/octave
50-800	0.32 g^2/Hz
800-2000	-6 dB/octave
2000	0.052 g^2/Hz
Overall	20.0 grms



3 minutes per axis, tested in x, y and z

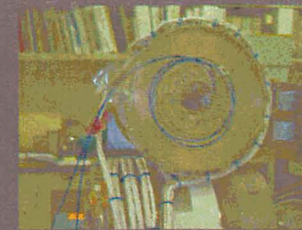
Both LR and LOLA Assemblies

Thermal Qualification Data on Laser Ranging Optical Assemblies



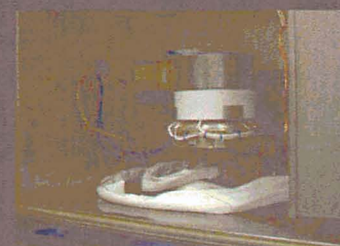
LRO Laser Ranging Cold Gimbal Motion Life Testing

Gimbals



Window inside gimbal; Flexlite cable inside

Window inside gimbal; Bundle cable inside.

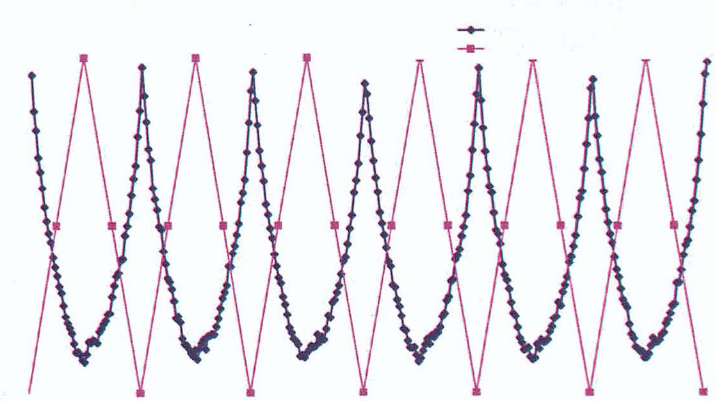


Gimbals w/ single flexlite in thermal chamber

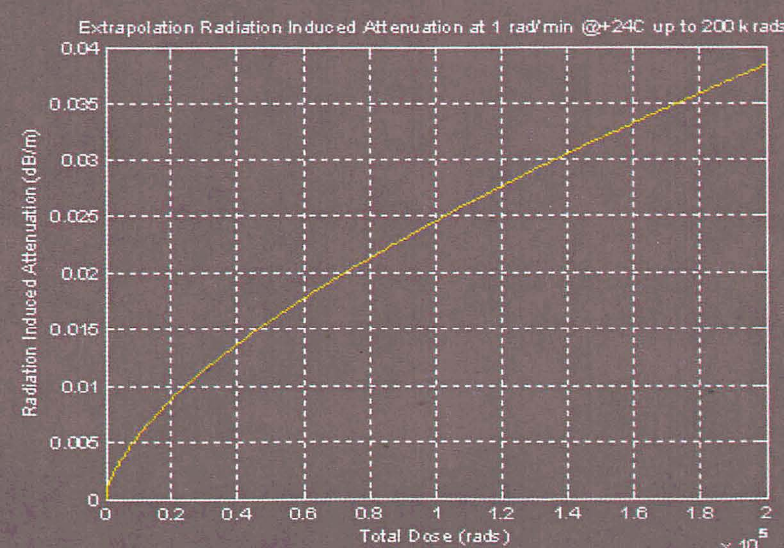
Gimbals w/ bundle in thermal chamber

LRO Laser Ranging Bundle Cold Gimbal Motion Testing Results

End of Test, relative IL ~ 0.50 dB, @ 850 nm, -20°C, 400/440 FV flexlite in Bundle

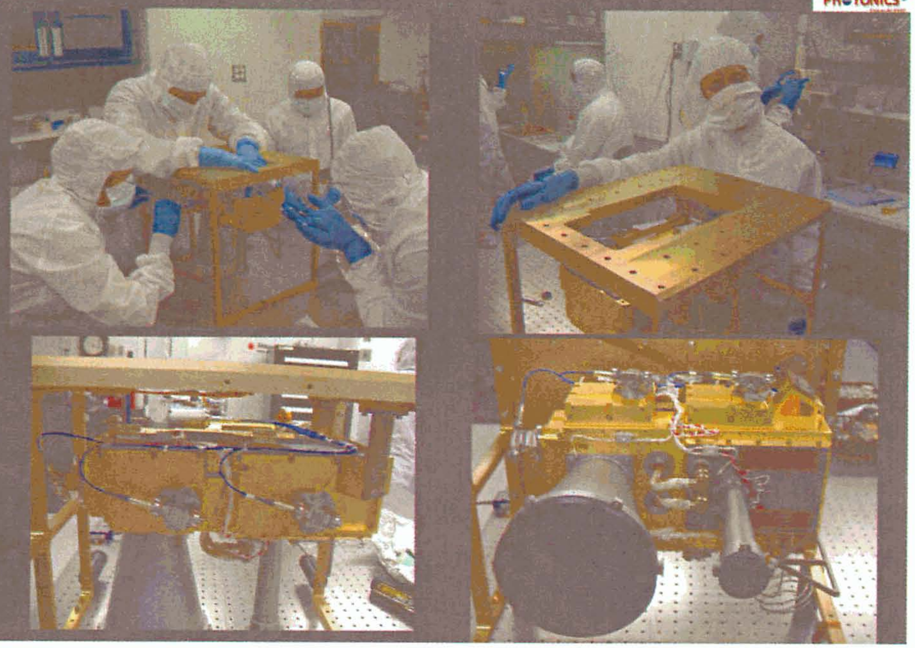


Radiation Testing and Modeling



$A(D) = 1.4516 * 10^{-4}\phi^{1-0.6412} D^{0.6412}$

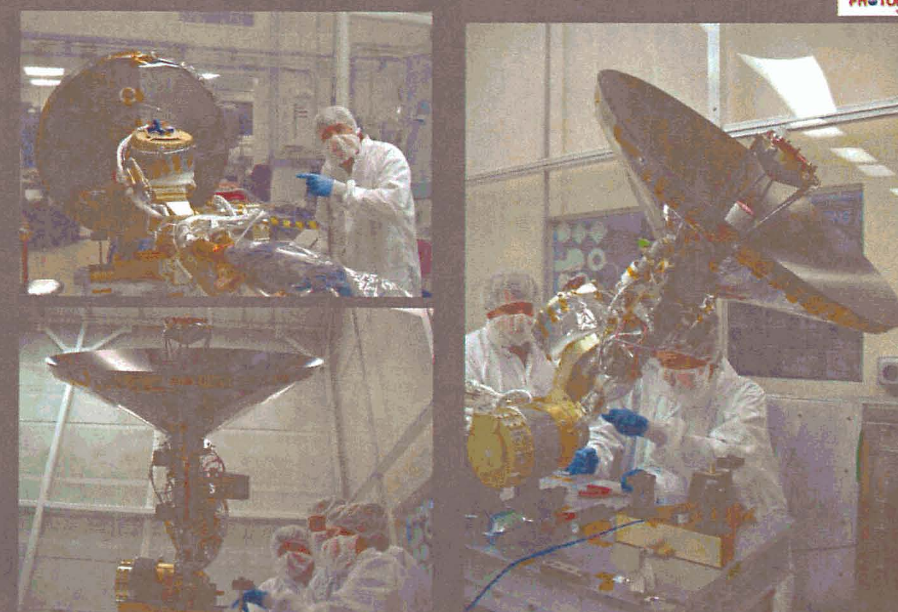
LOLA Integration, October 2007



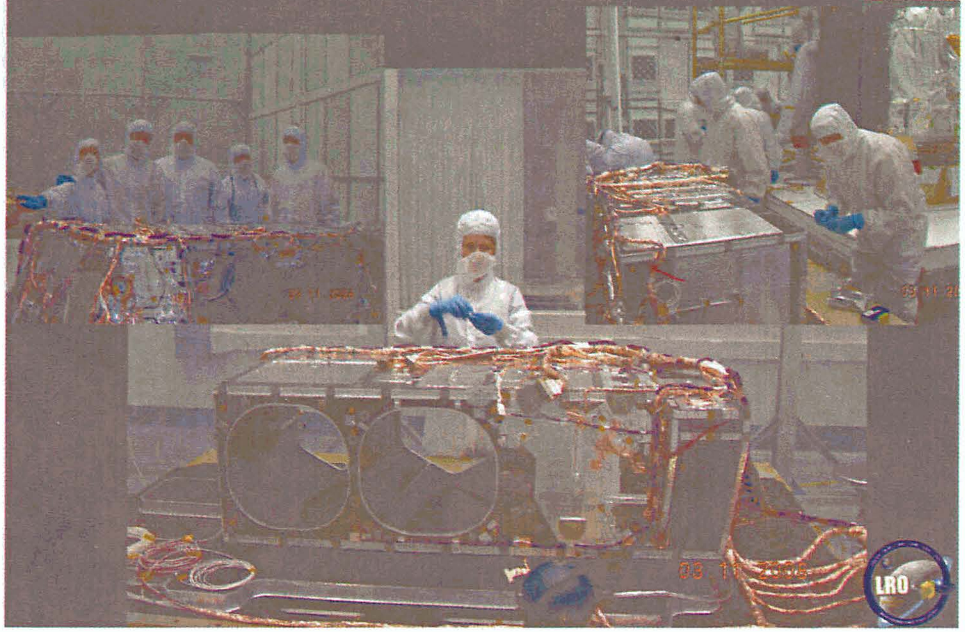
Gimbal Integration, December 2007

LRO Integration HGAS, 02-2008

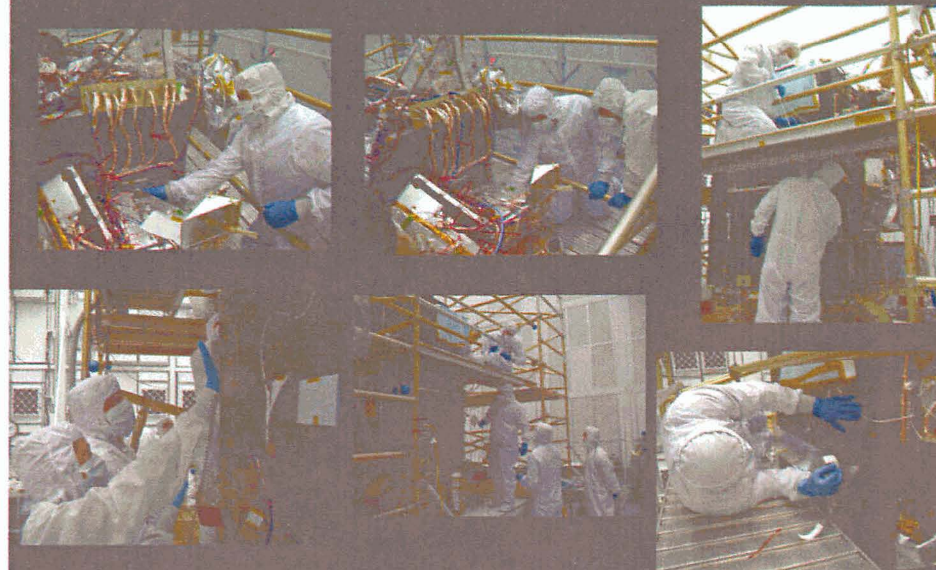
Lunar Recon. Orbiter - LRT & HGAS, 02-2008



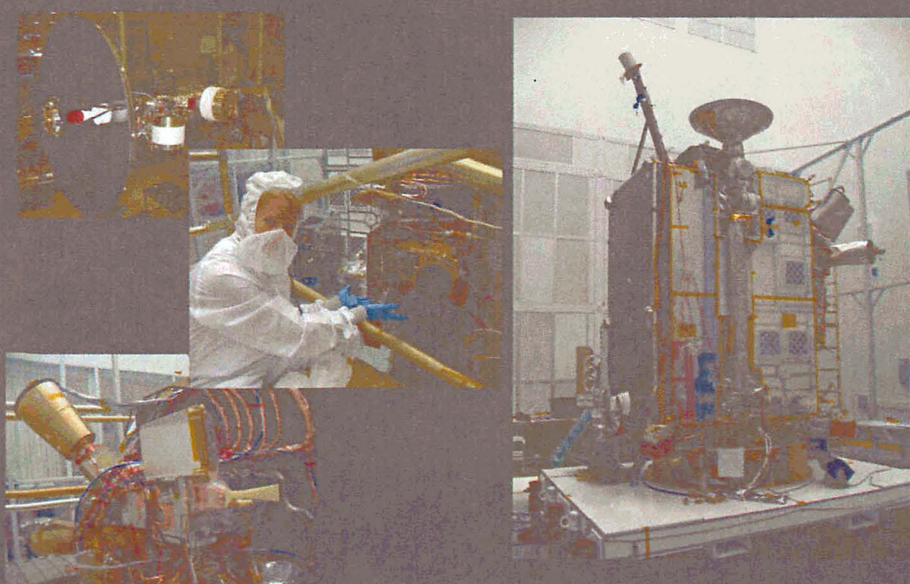
LRO Integration @ IM Deck, 03-2008



LR Segment 3 Flight Routing, April 2008



Additional Pictures of LRO, June 2008 Integration Complete



2008 New Capability
19 Fiber Arrays with Linear to Bundle Mapping

Conclusion

Do Not Go Where the Path May Lead,
Go Instead Where There Is No Path
and Leave a Trail….

- Ralph Waldo Emerson

Thank you
for the invitation!

For more information please visit the website:

misspiggy.gsfc.nasa.gov/photonics
NEPP.nasa.gov